EXECUTIVE SUMMARY

ES.1 INTRODUCTION

On April 9, 1998, at approximately 11:28 pm, an 18,000-gallon propane tank exploded at the Herrig Brothers Feather Creek Farm (the farm) in Albert City, Buena Vista County, Iowa. The explosion killed two volunteer fire fighters and injured seven other emergency response personnel. Several buildings were also damaged by the blast.

ES.2 INITIATING EVENT

The farm raised turkeys, which were housed in seven barns. Space heaters and furnaces provided heat for these turkey barns. Fuel for these space heaters and furnaces was supplied by a propane storage and handling system that included the propane tank that exploded.

On the evening of the incident, eight high-school-aged teens gathered at the farm for a party. According to one of the co-owners of the farm, the youths had attended similar social gatherings at the farm on other dates, but with neither the knowledge nor the consent of the owners. Neither owner lived at the farm.

At approximately 11:00 pm, one of the youths began driving an all-terrain vehicle (ATV) around the farm. Then the driver of the ATV picked up a passenger and continued his ride. The ATV was heading east between the propane tank and a turkey barn when it struck two aboveground propane pipes (liquid and vapor lines) that ran parallel to one another from the propane tank to direct-fired vaporizers approximately 37 feet to the north of the tank. (The direct-fired vaporizers were components of the system that used heat to transform liquid from the tank into a

gas that was piped to space heaters and furnaces on the farm.) The ATV damaged both the liquid and vapor lines.

The liquid line (which measured approximately ¾-inch inside diameter) was completely severed from the tank at the location where it was connected to a manual shut-off valve directly beneath the tank. An excess flow valve protecting the liquid line failed to function, and propane leaked out of the tank at the point of the break. As the liquid propane sprayed out of the tank, it rapidly changed to vapor. Propane vapor may have also leaked from the damaged vapor line. Within a few minutes, propane from the damaged lines ignited, most likely when it reached one of the direct-fired vaporizers approximately 37 feet away. A fire, fed by the broken liquid line, began burning vigorously under the tank. Two of the teenagers drove to the home of a neighbor, approximately ½ mile from the farm, to report what had happened. At 11:10 pm, the neighbor called the 911 operator to report the fire.

Twenty members of the Albert City Volunteer Fire Department and two Buena Vista County Sheriff Deputies were the first responders to reach the farm. Upon arrival at about 11:21 pm, the fire fighters observed flames originating from two primary locations: from under the west end of the tank and from the pressure relief valve pipes located on the top of the tank. One fire fighter reported that the "west end of the tank [near the broken liquid line] was *engulfed* in flames" (emphasis added). Another stated that "the propane tank was fully engulfed and flames were 70-100 yards in the air." Fire fighters stated that the noise from the pressure relief valves was "like standing next to a jet plane with its engines at full throttle."

At approximately 11:28 pm, as fire-fighting equipment was being moved into position, the tank exploded, scattering metal tank fragments in all directions. One large piece of the tank traveled in a northwesterly direction, striking and killing two volunteer firemen. Seven other emergency personnel sustained injuries as a result of the explosion.

ES.3 KEY FINDINGS

- The explosion that occurred at the farm is known as a Boiling Liquid Expanding Vapor Explosion or BLEVE. A BLEVE can occur when a pressure vessel containing a flammable liquid, like a propane tank, is exposed to fire. The book, *Loss Prevention in the Process Industries*, provides the following description of a BLEVE:

  > When a vessel containing a liquid under pressure is exposed to fire, the liquid heats up and the vapour pressure rises, increasing the pressure in the vessel. When this pressure reaches the set pressure of the pressure relief valve, the valve operates. The liquid level in the vessel falls as the vapour is released to the atmosphere. The liquid is effective in cooling that part of the vessel wall which is in contact with it, but the vapour is not. The proportion of the vessel wall which has the benefit of liquid cooling falls as the liquid vaporizes. After a time, metal which is not cooled by liquid becomes exposed to the fire; the metal becomes hot and then may rupture.

- In this incident, the tank was engulfed in flames due to a leak of propane under the tank. These flames created the conditions that produced the BLEVE.

- Neither the propane tank nor its aboveground piping were protected by a fence or any other physical barrier designed to prevent damage from vehicles.

- The propane tank was equipped with an excess flow valve to protect the tank's liquid line leading to the vaporizers. In the event of a complete break in the liquid line downstream from the valve, it was designed to close and greatly reduce the flow of propane from the broken pipe. (Even when an excess flow valve is activated, a small amount of fluid bleeds through a tiny hole in the valve. Consequently, installation of a shut-off valve immediately downstream from the excess flow valve is required to stop all flow.) When the ATV severed the liquid line at this installation, however, the excess flow valve failed to close because the flow capacity of the outlet piping system downstream of the valve was less than the closing rating of the excess flow valve installed in the tank.

- Fire fighters were positioned too close to the burning propane storage tank when it exploded. They believed that they would be protected from an explosion if they avoided the ends of the tank.

- The propane storage and handling system was installed at the farm in 1988. When the tank system was installed, Iowa law provided that the 1979 edition of the National Fire Protection Association's *Standard for the Storage and Handling of Liquefied Petroleum Gases* (NFPA 58) governed the installation. Under NFPA 58 and other relevant Iowa law, the State Fire Marshal should have received a plan of the farm's propane tank storage and handling system before it was installed. Iowa law, however, did not specifically designate which party -- the owner or the installer of a large propane storage facility -- was required to notify the State Fire Marshal. The CSB's investigation revealed that the State Fire Marshal had no record of the system and that it was not installed in compliance with all NFPA 58 requirements adopted as Iowa law.

Root Causes

1. Protection for aboveground piping was inadequate.

Two aboveground pipes (liquid and vapor lines) that ran from the propane storage tank to its vaporizers were not protected from potential physical damage from vehicles. Lack of piping protection allowed a vehicle to crash into these pipes, breaking them and releasing the propane that ignited.

2. The diameter of the pipe downstream from an excess flow valve was too narrow, which prevented the valve from functioning properly.

An excess flow valve that was designed to stop the flow of all but an extremely small amount of liquid propane in the event of a severed line did not function because the diameter of the pipe downstream from the valve was too narrow to allow the valve to activate. Post-incident tests of the valve showed that it would have operated as designed if the pipe downstream had been the proper size. A functioning excess flow valve on the liquid line would have greatly reduced the severity of the fire that engulfed the tank. This likely would have prevented the BLEVE.

3. Fire fighter training for responding to BLEVEs was inadequate.

Some training materials provided to the fire fighters led them to believe that they would be protected from a propane tank explosion by positioning themselves to the sides of the tank and by avoiding the areas extending from the two ends of the tank. As a consequence, fire fighters were positioned too close to the sides of the burning propane storage tank when it exploded. Fire fighters did not adequately recognize the potential for a BLEVE and that a BLEVE can scatter tank fragments in all directions. In this incident, flying tank fragments from the explosion killed two fire fighters located approximately 100 feet from the side of the tank.

Contributing Cause

The State Fire Marshal did not detect deficiencies in the design and installation of the propane storage facility.

Under Iowa law, the State Fire Marshal should have received a plan of the farm's propane system prior to its installation in 1988. The State Fire Marshal had no record of the farm's system, however. Iowa law did not specifically designate which party -- the owner or the installer of a large propane tank facility -- was required to notify the State Fire Marshal. In addition, the State Fire Marshal did not have a program in place to adequately monitor or inspect large propane storage facilities.

ES.4 RECOMMENDATIONS

Herrig Brothers Farm

1. Install protection (i.e., fencing or barricades) to protect aboveground propane pipes from possible damage from vehicles.

2. Install properly sized propane outlet piping from excess flow valves.

Iowa State Fire Marshal

Develop a program to ensure implementation of the requirements of the National Fire Protection Association's *NFPA 58* S*tandard for the Storage and Handling of Liquefied Petroleum Gases,* as adopted by Iowa law. Ensure that this program includes, at a minimum, the following elements:

- Designation by regulation of the party (such as a facility owner or installer) who is responsible for submitting planned construction or modification documents to the State Fire Marshal;
- Procedures for approving the plans for new or modified installations;
- Procedures governing the issuance and posting of permits authorizing the use of equipment; and
- On-site inspections of new, modified, and existing propane and other Liquefied Petroleum Gas storage facilities that are covered by Iowa state law.

Fire Service Institute of Iowa State University

Ensure that fire fighter training materials address proper response procedures for BLEVEs.

National Propane Gas Association (NPGA)

1. Ensure that fire fighter training materials address proper response procedures for BLEVEs.

2. Distribute the CSB findings and recommendations in this report to NPGA members.